CONTROL CHART FOR CONTINUOUS QUALITY IMPROVEMENT - ANALYSIS IN THE INDUSTRIES OF BANGLADESH

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ABSTRACT

This research aimed for collecting data relevant to statistical process control from prominent manufacturing industries in Bangladesh and analyze the current situation of quality control in production line and apply statistical process control tools, particularly, Control chart, to identify defects. Engineers do not design inferior quality. Usually, in a certain stage of the system, in all scenarios of manufacturing or service industries, defects occurs that cause worse quality. Statistical process control (SPC) is a great tool to explore those variations. The author performs time series analysis using line graph and control chart to evaluate the system quantitatively. This article provides an overview of control chart regarding manufacturing industries in Bangladesh and implement control chart to remove out of control scenarios from the manufacturing processes. After analyzing the data obtained from the manufacturing system, out of control or defective data point has been discovered and removed, and thereafter the system is in control.

Key Words: Control Chart, Statistical Process Control, Data Mining

1.0 INTRODUCTION

The theory of statistical process control was developed by Dr Walter Shewhart, and was popularized by Dr W Edwards Deming. Both observed that repeated measurements from a process will exhibit variation - Shewhart and Deming realized that their observation could be applied to any sort of process. If a process is stable, its variation might be predictable and can be described by one of several statistical distributions.

Statistical process control is a collection of tools that, when used together, can outcome in process stability and variance reduction. Control charts have been used in SPC for measuring the variation in the process and that can be continuously developed by the different techniques used in the SPC such as basic seven quality control tools (e.g. Check Sheet, Cause-and-Effect Sheet, Flow Chart, Pareto Chart, Scatter Diagram, Histogram, and Control Charts).

Control charts are an essential tool of continuous quality control1. If there is any change in the process, control charts monitor processes to show how the process is performing and how the process and capabilities are affected by changes to the process over time. This information is then used to make quality improvements. They can help to identify special or assignable causes for factors that hinder ultimate performance.

The rest of article is organized as follows. Section 2 describes the literature review, Section 3 establishes the methodology applied, Section 4 depicts the experimental details, Section 5 shows the result and discussion, and Section 6 includes the conclusion.

2.0 LITERATURE REVIEW

SPC is a statistical based approach that determines whether a process is stable or not by discriminating between common cause variation and assignable cause variation. A process is said to be “stable” or “under control”, if it is affected by common causes only. Control Chart is a strong tool in SPC. Each control chart estimates process performance by comparing it with a measure of its central tendency, an upper and lower limit of admissible performance variations[2, 3,4.]

Now, let’s move onto the point how to economically maintain the product quality level is a critical issue for the Multistage Manufacturing System (MMS)[5], in which each station may inevitably shift to the out-of-control condition resulting in higher nonconforming rate and larger quality loss. Ongoing inspection on real production time can tremendously help engineers to reduce defects in production line[6].

On the basis of probability as defined by Tshebycheff's inequality, Shewhart[7] originally chose three standard errors (3-sigma units) as the marker for data points exceeding the limits of statistical control. This inequality states that no less than 89% of a sampling distribution, no matter the shape, lies within three standard errors of its mean.

In general,

$P(\mu - k\sigma \leq X \leq \mu + k\sigma) \geq 1 - 1/k2$

for every $k > 0$.

If the underlying distribution is normal and the process is in control, 99.73% of the monitored means lie within these 3-sigma control limits. On the other hand, if the statistics to be monitored were not normal, at worst, 89% of these would be within the control limits. With a more refined version of Tshebycheff's inequality[8,9] for strongly unimodal statistical distributions (e.g., that of the standard deviation estimator, s), at least 95% of the monitored statistics would be within the limits. For the Shewhart Mean ($\overline{X}$) chart, by virtue of the central limit theorem, normality further increases the percentage of means within 3-sigma control limits to around 99.73%. Researchers have found nonnormality effects on Shewhart control charts to be minimal[10,11].

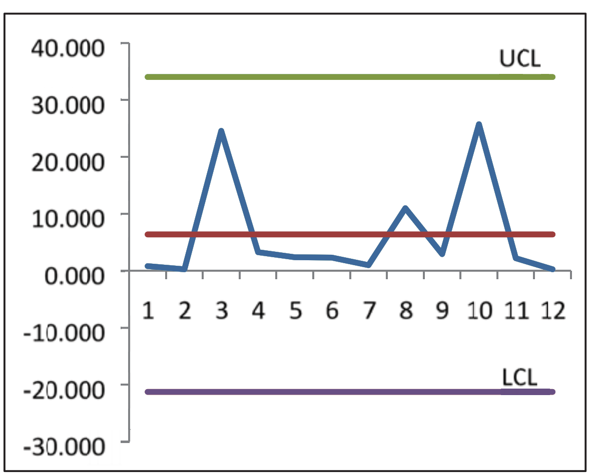

Fig1: Control Chart with 3 sigma control limit

Generally, the choice of 3-sigma for control limits is determined by keeping a proper balance between control for Type I and Type II errors. For manufacturing processes, Shewhart also found the coefficient 3 to be excellent in providing this balance[12]. As a result, the American Society for Testing and Materials printed tables for control limits using 3-sigma for $\overline{X}$ and standard deviation (s) charts. Although the manufacturing industry has widely adapted these 3-sigma limits for their processes, other coefficients may be reformed for a particular application by carefully balancing the effects of Type I and II.

Naturally, companies do not usually measure all products as this may be counterproductive or economically unfeasible. As a negotiation, most companies select rational subgroups of products often using a random sampling scheme[13]. These subgroups are then laboriously checked for quality and their summary measurements have been charted for quality control purposes since last century.

With emphasis on early detection and prevention of the problems, SPC has a discrete benefit over other quality approaches such as inspection of end product[14]. SPC necessitates distinct processes and a discipline of following them. It requires an atmosphere where employees are not penalized when problems are detected.[15]

3 METHODOLOGY

3.1 Problem Statement

The problem to be solved in the research work is to collect data and identify the *special causes of variation* in the industrial systems by control chart and improve the sigma level.

Data collection methods used in this research involves the use of observation, company documents and structured experiments. After gathering all necessary information, statistical methods have been implemented to find the defects. A statistical approach has been taken to eliminate all nonconforming products by full inspection and detect the out-of-control occurrence using statistical process control (SPC) techniques, in this research work, we have applied Control Chart. introduction of a system to eliminate all nonconforming products by full inspection and detect the out-of-control occurrences using statistical process control

(SPC) techniques is required. In this research work, Control Charts have been applied.

3.2 Choice of Control Chart

Depending on observation type, we decide what type of control charts best suited the scenario. For example, for variable data, we may use Xbar-R chart, for attribute data, we would adapt p-chart or np-chart.

3.3 Mathematical Model

If the process is in control, almost all points will lie within the upper control limit (UCL) and the lower control limit (LCL).

These control limits are chosen so that if the process is in control, nearly all of the sample points will fall between them. If all the data points are situated between the control limits, the process is presumed to be in control, and no action is necessary. However, a data point that plots outer of the control limits is interpreted as evidence that the process is out of control, and investigation and corrective action are required to find and remove the common and special causes responsible for this performance. It is customary to connect the sample points on the control chart with straight-line segments, so that it is easier to visualize how the sequence of points has evolved over time.

Even if all the points plot inside the control limits, if they behave in a systematic or nonrandom manner, then this could be an indication that the process is out of control. For example, if 18 of the last 20 points plotted above the center line but below the upper control limit and only two of these points plotted below the center line but above the lower control limit, we would be very suspicious that something was wrong. Once the process is in control, all the plotted points would have a random pattern. Methods for looking for sequences or nonrandom patterns can be applied to control charts as an aid in detecting out-of-control conditions. Usually, there is a reason why a particular nonrandom pattern appears on a control chart, and if it can be found and eliminated, process performance can be improved.

Control limits for X-bar chart:

For a Shewhart $\overline{X}$ SPC chart, past information or contractual specifications on the products' mean and standard deviation are helpful to set up limits for the process. In industrial SPC applications, these means and standard deviations are often called "control" or "target" values. The formula is,

$$UCL(\overline{X}) = \overline{\overline{X}} + A_2\overline{R};$$

$$UCL(\overline{X}) = \overline{\overline{X}} - A_2\overline{R}$$

Control limits for R-chart:

Calculate the control limits for the R chart. The upper control limit is given by UCLr. The lower control limit is given by LCLr.

The formula is,

$$UCL_r = D_4 \overline{R}$$

$$LCL_r = D_3 R$$

4.0 EXPERIMENTAL DETAILS

4.1 Data Collection

SPC data has been collected in the form of measurements of a product feature or process instrumentation readings. The data is then recorded and tracked on various types of control charts, based on the type of data being collected. It is imperative that the correct type of chart is used gain value and obtain useful information. The data can be in the form of continuous variable data or attribute data. The data can also be collected and recorded as individual values or an average of a group of readings.

To conduct our research, and implement the methodology proposed, we have consulted with two companies in Bangladesh, namely DBL Group and Bangladesh Lamps Limited-Transcom. In this section, data collection method for these two companies will be described.

In DBL Group, data collection is exclusively based on their Knitting division. Most observations are recorded manually on forms customized to collect specific information then input into a computer database (Microsoft Excel). Data is also taken automatically through the use of automated devices that send information directly to a database.

In particular, most of the data are related to the buyer wise order receiving and delivery Status in 2016. Additionally, the records related to wastage from garments, and the reasons for revision for different products are collected. Moreover, the wastage info of Jute (fabric wastage, fabric cutting, and jute Sewing) are being prepared.

We have examined the improvement of the quality of product in the samples of apparel products in Knitting division of DBL Group, Gazipur, Bangladesh during 2015 – 2017. The main reasons for revision of the products are tabulated in Table 1: Reason for revision.

One crucial question to be answered is how to increase the number of client order at Knitting division at DBL?

Table 1: Reason for revisions

Reason for revision (only few reasons are enlisted)
Change in quality either better or worse Change in fabric parameters Increase in consumption for Nk Rib Fabric. Additional fabric needed for Bk Nk Tape.

Bangladesh Lamps Limited (BLL) is one of the leading manufacturers of electric light bulbs in Bangladesh. In this research work, the real time data of the manufacturing process has been gathered from appropriate sources at BLL. In Bangladesh Lamps Limited, there are several parameters that are being considered during the data collection process. The rejections on testing board, month-wise average rejection percentage over a period of seven months up before and after packing has been considered. Additionally, major faults in the production line along with total checking quantity, total rejection quantity, percentage of Rejection are being assembled.

Furthermore, data regarding production and packing process has been considered where production process involves sealing reject, exhaust reject, aging good rejection, lost and packing process involves cap bend, black and bad stamp, bad flash, anode strip, no burn, bad solder packing, discount lamp rejection.

4.2 Analytics

In this study, we explored the use of SPC charts with a real data set for two industries in Bangladesh. Because SPC charts have not previously been used extensively in the manufacturing companies in this country, the findings from the research would, hopefully, give the engineers and quality control specialist to embrace the idea of SPC to improve their system efficiency.

4.2.1 Scenario 1: DBL group (Knitting division)

Regression analysis is conducted to test for statistically significant slope ($\alpha = 0.005$).

Figure 2 depicts the Xbar-R chart where in R chart, three data points are out of control. Therefore, we would be going to drop them by adjusting the system parameters. Technically, we need to figure out the special causes of variation for these 3 data points.

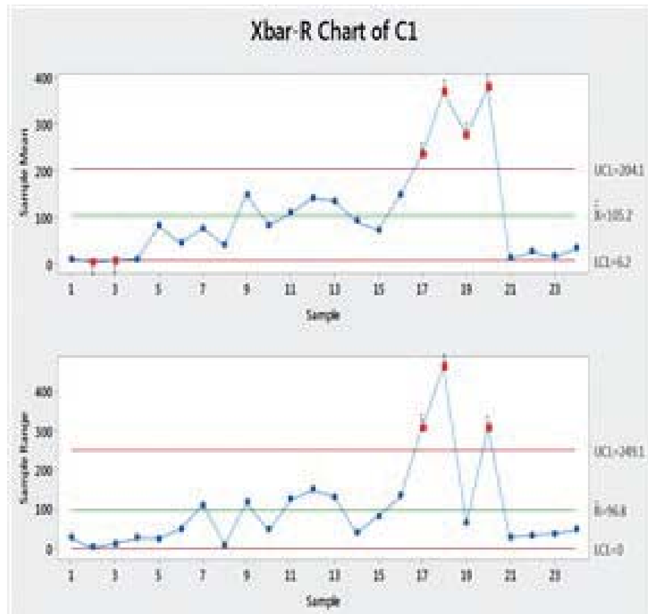

Fig 2: Xbar-R chart for the Yarn wastage from outside in Knitting division in DBL

In DBL group, we observed that the number of order is highly frequent for smaller number of products. For example, in Figure 3, we infer that when the number of product is less than one hundred and twenty, the order is highly likely to happen.

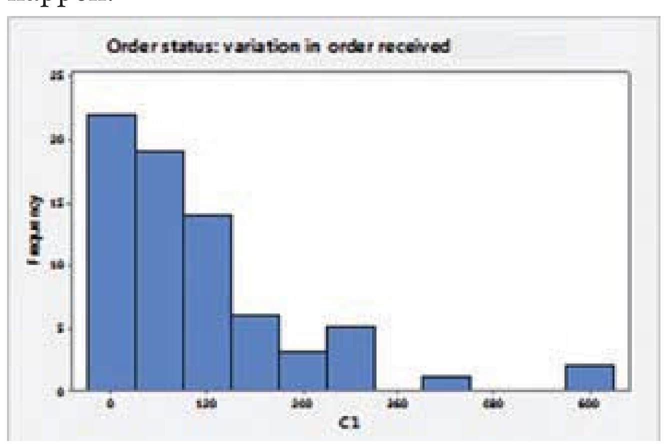

Fig 3: Frequency of the client order received

Rational sub group

An essential idea in the application of control charts is the group of sample data according to what Shewhart called the rational subgroup concept. To illustrate this concept, we have been used a control chart to detect changes in the process mean in Figure 2. The rational subgroup concept implies that subgroups or samples should be selected so that if assignable causes are present, the chance for variances between subgroups will be exploited, while the chance for differences due to these assignable causes within a subgroup is plausible to minimize.

To perform an exploratory data analysis, stem and leaf display has been produced from the data gathered. The implied purpose of this display is to show the relative density and shape of the data, giving us a quick synopsis of distribution as in Figure 4.

Stem-and-Leaf Display: C1

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Stem-and-leaf of C1  N  = 2075
Leaf Unit = 10000

(1796)                                        0
00000000000000000000000000000000000000
0000000000000000000000000000000000000
0+
 279                                          0
22222222222222222222222222222222222222
2222222222222222222222222222222222222
2+
 106                                          0
4444444444444444444444444444444444444
44455555555
 56    0  6666666666666666667777777777777
 25    0  88888888999
 14    1  000011
 8     1  2
 7     1  55
 5     1  677
 2     1
 2     2
 2     2
 2     2
  2     2  67
```

Fig 4: Stem and Leaf display

4.2.2 Scenario 2: Bangladesh Lamps Limited-Transcom

After assignable causes have been removed, statistics can be used to develop an accurate overview of the process.

Pareto charts in Figure 5 shows what features need the most work by displaying them in the order of most defects to fewest.

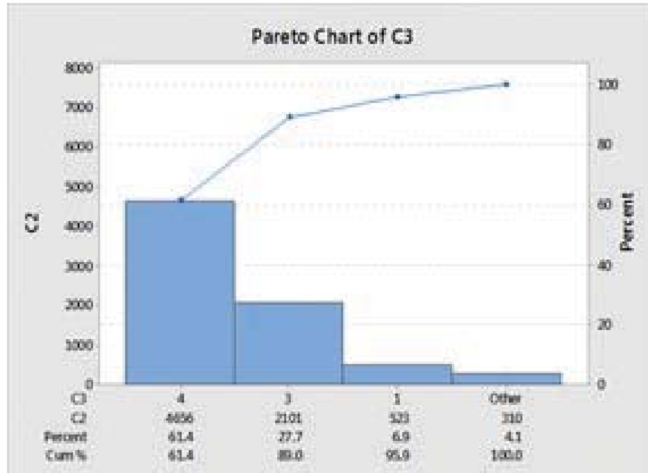

Fig 5: Pareto chart

Deviations in measurements in Bulb manufacturing line in different parameters (Bangladesh Lamps Limited - Transcom) are enlisted in Appendix1. The following figures are the experimental results of Control chart e.g. Individuals Chart and Moving Range Chart for the given scenario.

The example illustrates in Figure 6 the control chart for individual observations. A process in BLL was studied in order to monitor the quality in the production line.

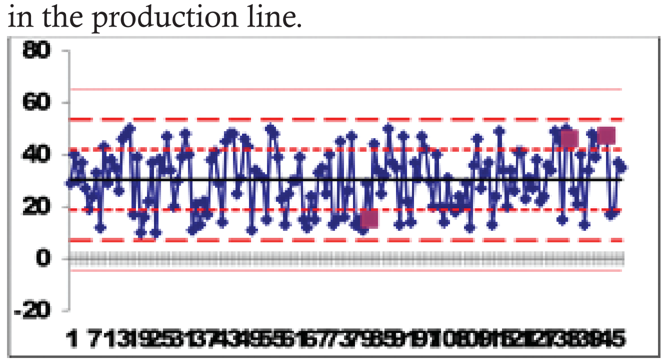

Fig 6: Individuls Chart

In our case, it is worthwhile to use the median of the moving range rather than its average, as the calculated range data contains a few large values that may inflate the estimate of the population's dispersion. Figure 7 represents the scenario for product rejection in different parts, namely filament, flange tube, shell and so on. In Figure 7, points outside of the control limits are signals demonstrating that the process is not operating as steadily as expected. We can interpret that several assignable causes have resulted in a change in the process at BLL.

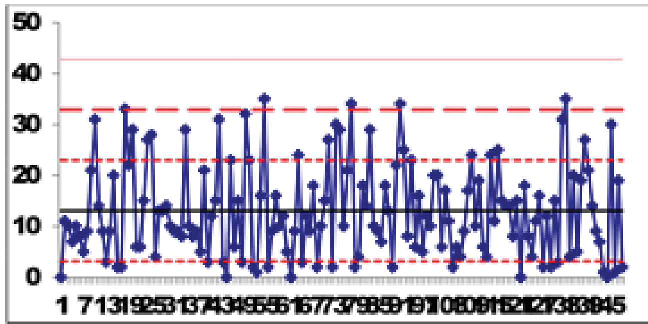

Fig 7: Moving Range Chart

Table 8: Data of Control Chart

Name	Value	Name	Value	Name	Value
Xbar/IMR Chart Avg	30.407	Xbar one sigma Upper Limit	42.02	Rbar one sigma Upper Limit	23.01
Range Chart Avg	13.101	Xbar two sigma Upper Limit	53.64	Rbar two sigma Upper Limit	32.93
Rbar/d_2	11.61407	Xbar three sigma Upper Limit	65.25	Rbar three sigma Upper Limit	42.84
Number of samples	150	Xbar one sigma Lower Limit	18.79	Rbar one sigma Lower Limit	3.188
Subgroup size	1	Xbar two sigma Lower Limit	7.175	Rbar two sigma Lower Limit	n/a
Number of subgroups	150	Xbar three sigma Lower Limit	-4.44	Rbar three sigma Lower Limit	n/a

The data summary of the control charts for the data set of BLL is listed in Table 8. Here, the number of sample is 150, three sigma limit has been implemented as guided by researchers.

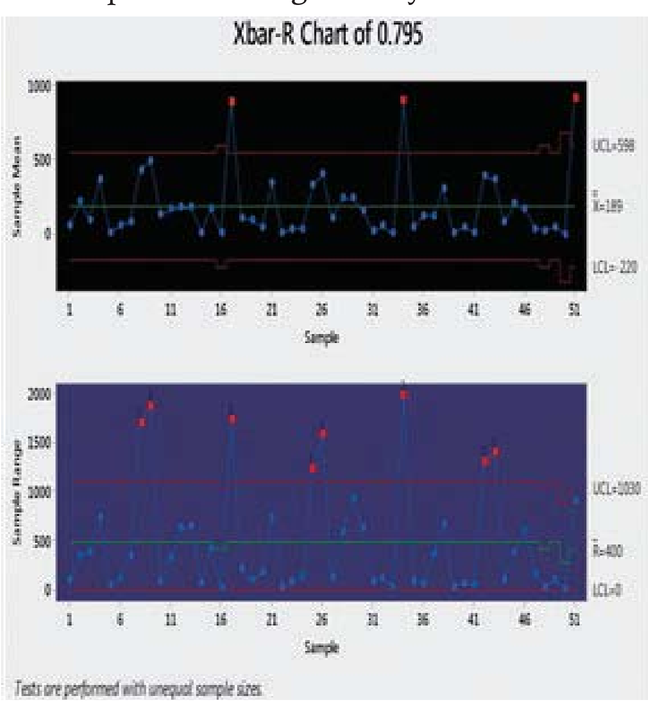

Fig 9: Xbar-R chart

All control charts have used three sigma limits and have been generated using Minitab software version 17. Some of the statistical analyses have been performed using Microsoft Excel 2016.

5.0 RESULT AND DISCUSSION

In the data set of DBL Group, Control charts are implemented to monitor the stability of processes. A time-ordered data for a particular characteristic are taken – in DBL group, the amount of warn wastage are taken into account - into a picture that is convenient to comprehend in Figure 2, 3,4. These charts indicate when there are points out of control or unusual shifts in a process. Control chart in Figure 2 perceives the nonrandom sources of variation in the data.

In the data set of Bangladesh Lamps Limited - Transcom manufacturing system, in Figure 6 (Individual Chart) we examine 3 outliers. We have got eight data point lie outside of the control limit in Figure 8. By knowing the root cause of the defect, and eliminating the defects, we would be able to reestablish the control chart, which is our future work.

By moving the control limits farther from the center line, we decrease the risk of a type I error - that is, the risk of a point falling beyond the control limits, indicating an out-of-control condition when no assignable cause is present. On the other hand, spreading the control limits will also surge the danger of a type II error - that is, the jeopardy of a point falling between the control limits when the process is really out of control. If we move the control limits closer to the center line, the opposite effect is obtained: The risk of type I error is increased, while the risk of type II error is decreased. Even though other interpretations and creations of these data are possible, we believe that ours are probable and hope they are valuable.

5.1 Need for SPC in Bangladesh

By visualizing data, we can easily detect defects in manufacturing process. In Bangladesh, most of the industries are still considered to be lagging behind to apply statistical process control methodologies to improve the quality of the system.

The introduction of the SPC system as a tool would greatly enrich the quality aspects in the system. The use of SPC is expected to assist in solving common quality related problems and ought to be maintained by topper management levels in the industries in Bangladesh.

5.2 Future Work

From this research endeavor, we know the exact place where the defects would occur in the system. The future work will involve identifying the reasons of the defects, and eliminating them with appropriate quality engineering tools.

6.0 CONCLUSION

In this study, we have applied control chart to visually and quantitatively examine the variation in manufacturing process. The control chart in Figure 8 clearly shows us the data points which are far away from the mean or expected value as per engineering specification.

In summary, the practice of the SPC tools is very little because of the challenges systems are facing in Bangladesh or other developing countries. Hence, some serious motivation and inspiration are mandatory to put the manufacturing on a consciousness initiative to adapt SPC.

Although SPC tools are commonly implemented, control chart in particular, in the manufacturing industries of most developed countries; we do not see any proper implementation of SPC in Bangladeshi industries. Therefore, embracing the idea of SPC in the industries in Bangladesh is highly recommended.

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Appendix[1]

Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data
1	29	26	34	51	34	76	26	101	20	126	27
2	40	27	47	52	32	77	47	102	14	127	38
3	30	28	34	53	31	78	13	103	31	128	22
4	37	29	20	54	15	79	15	104	20	129	24
5	27	30	30	55	50	80	11	105	18	130	36
6	19	31	39	56	48	81	29	106	24	131	34
7	24	32	48	57	39	82	15	107	20	132	49
8	33	33	40	58	23	83	44	108	29	133	46

9	12	34	11	59	13	84	34	109	12	134	15
10	43	35	21	60	25	85	25	110	36	135	50
11	29	36	13	61	30	86	32	111	46	136	46
12	38	37	22	62	30	87	50	112	27	137	26
13	35	38	17	63	39	88	37	113	33	138	21
14	26	39	38	64	15	89	35	114	37	139	40
15	46	40	41	65	12	90	13	115	13	140	13
16	48	41	29	66	24	91	47	116	24	141	34
17	50	42	14	67	15	92	22	117	49	142	48
18	17	43	45	68	33	93	14	118	34	143	39
19	39	44	48	69	35	94	37	119	20	144	46
20	10	45	48	70	25	95	31	120	34	145	47
21	16	46	25	71	40	96	47	121	26	146	47
22	22	47	31	72	13	97	42	122	41	147	17
23	37	48	46	73	15	98	30	123	41	148	18
24	10	49	43	74	45	99	20	124	23	149	37
25	38	50	11	75	16	100	40	125	31	150	35

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